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SANITATION TREATMENT for Insect Control

Forest Service

U. S. Department of Agriculture

California

1965

INTRODUCTION

In arid and urbanized southern California, the limited forest land of the mountains is a treasure of immeasurable value. Within a few hours drive of metropolitan areas, such as Los Angeles, there are several National Forests. These cool, green, mountain top forests are visited by millions of people. They are familiar to many millions more through numerous movies and television programs.

The Forest Service, U. S. Department of Agriculture, is responsible for the management and protection of the Nation's National Forests. By law, the National Forests are required to be managed under the dual principles of sustained-yield and multiple-use (Acts of June 4, 1897; June 12, 1960, and others). The National Forests yield water, timber, forage, recreation, game and other wildlife as perpetually renewable resources and services. In southern California the National Forests are particularly valuable in protecting watersheds and furnishing opportunity for outdoor recreation. For these benefits it is important to maintain healthy, vigorous timber stands and to protect them from fire.

Small insects, commonly known as bark beetles, are the greatest threat to timber stands in southern California, even outstripping fire as the principal killer of trees. Although down through history, bark beetles have often destroyed large quantities of timber in southern California, they have made particularly serious inroads in these valuable stands during the past 10 to 15 years (fig. 1). There are several reasons for this: The area has been in the grip of a persistent drought, disturbance from the construction of highways and forest towns has greatly increased, several devastating fires have occurred, and a vast increase in the number of recreationists using local areas has depleted the forest litter and compacted the soil with heavy foot traffic and other activities. In the undisturbed forest, bark beetles subsist by breeding in decadent or injured trees and build up to epidemic numbers following natural disasters such as drought, forest fire or storm.

As a result of "urbanizing" the forest, the environment has been altered to conditions more adverse to tree growth and more favorable to bark beetle activity. To survive, the forest must be adapted by sound management practices to the new "normal" conditions which now prevail.

Figure 1. Part of the beetle-killed Coulter and Jeffrey pine stands on Baldy Mountain, San Bernardino National Forest. This stand was nearly destroyed by insects over a 4-year period.

Photo by Dr. R. C. Hall

Bark beetles are small, dark-brown to black insects about 1/5-inch long. They kill trees by attacking the trunk in large numbers, boring through the bark and excavating long tunnels in the cambium region of the tree. Both immature and mature stages of the beetles live and feed beneath the bark and the trees die from injury to the conductive tissue of the inner bark (fig. 2). The beetles killed over 20,000 trees in one growing season on three limited areas of the San Bernardino National Forest, according to estimates made by Pierce (Pierce, 1962):

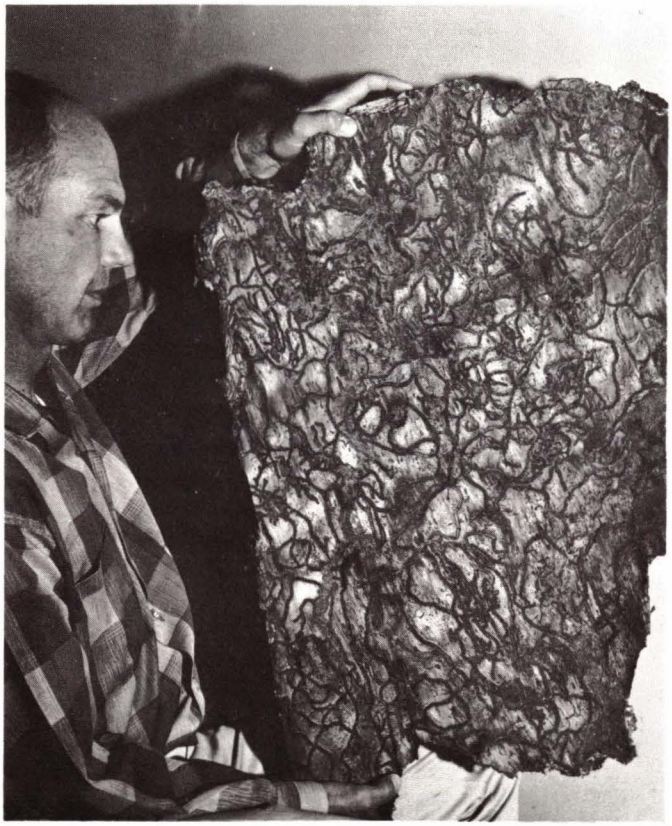
Area	Board Feet Killed	No. Trees Killed	Percent Stand Killed*
San Jacinto Mountains	3,630,000	13,500	2.2
Arrowhead	4,211,000	5,700	1.0
Barton Flats	1,271,000	1,750	2.0

* Based on board-foot volume.

When volume losses exceed 0.5 percent of the stand, the mature forest is suffering serious damage because losses have surpassed growth. The above figures, although derived from a broad survey rather than a detailed inventory, show that insect-caused tree mortality exceeded tolerable limits for sustaining the forest.

When bark beetles begin to kill large numbers of trees, the Forest Service is confronted with a very difficult problem. Hidden and protected as they are beneath the bark, it is difficult to find and kill a large percentage of the beetles over wide forested areas. Forest entomologists in California, as well as other parts of the country, have studied this problem for over 50 years to devise practical control methods. To date, two methods of control have been developed which have proven successful in California. One of these is called "Direct Control." Direct Control consists of locating trees which already have been attacked by the beetles, felling the trees and destroying the beetles beneath the bark with fire or insecticide. Occasionally the trees are physically removed, beetles and all, from the forested areas. The main failings of Direct Control are: High cost of accomplishment, near impossibility of finding all the infested trees before the beetles escape, and the fact that the treatment does little to alter any of the basic conditions which encouraged the outbreak in the first place.

The other proven method of control employs a silvicultural practice aimed at preventing bark beetle epidemics. It is called "Sanitation Treatment." This method is based on the discovery that in the more arid ponderosa and Jeffrey pine forests some trees are much more susceptible to bark beetle attack than others. A specialized system of identifying the most vulnerable trees has been devised. In applying sanitation treatment, the trees selected by this system are sold and removed by private timber operators under close Forest Service supervision. Removal of these bark beetle susceptible trees provides a high degree of protection for the rest of the stand. Usually only 10 to 15 out of each 100 trees must be removed to provide effective protection. The work is carefully done to avoid damage to watershed and aesthetic values of treated areas (fig. 3). The sanitation treatment usually safeguards the forest from bark beetle epidemics for periods of one or more decades, after which it may be necessary to repeat the treatment.



Tunnels in the inner bark of ponderosa pine.

Larva

Pupa

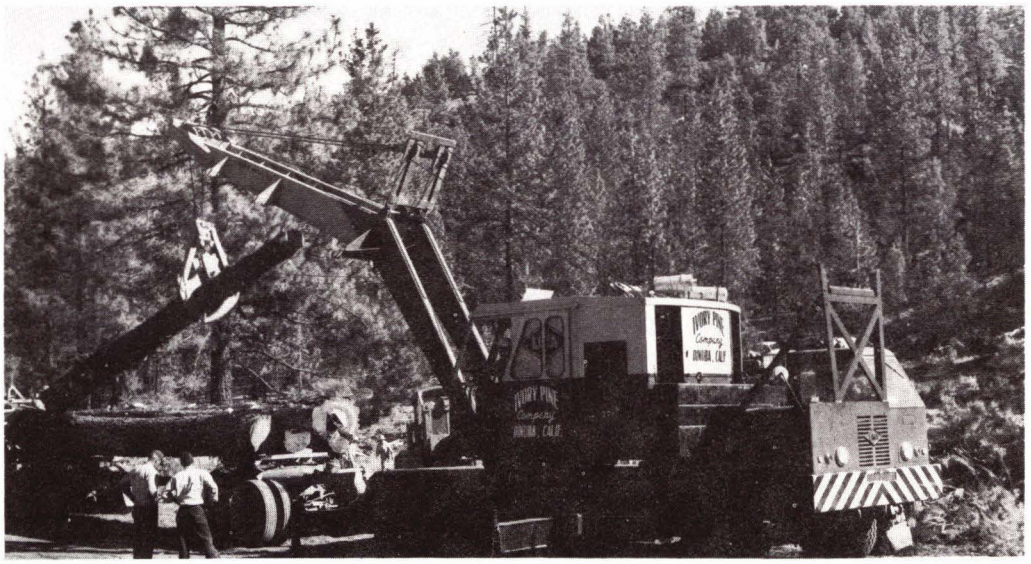
Adult

Figure 2. Life stages of the western pine beetle, (Dendroctonus brevicomis Lec.) and the damage they cause to the inner bark.

Photos by J. R. Pierce

Low stumps and careful work in the treating operation protects the scenic value of sale areas.

Photo by J. R. Pierce



Loading logs from a sanitation treatment operation for transportation to the sawmill.

Photo by J. L. Averell

Figure 3. Sanitation treatment in operation.

THE DEVELOPMENT OF THE SANITATION CONCEPT

As early as 1909, Hopkins (Hopkins, 1909) observed that many of the ponderosa pines attacked by the western pine beetles were large, over-mature trees, and that such trees appeared to be attacked more frequently than the thriftier, immature trees. In 1928, Person (Person, 1928) advanced the theory that slowly growing ponderosa pines were more frequently killed by the western pine beetle than faster growing ones.

In 1936, Salman (Salman, 1937) devised a system called "risk rating" whereby the current health of a ponderosa pine was evaluated by the degree of decadence in the tree's crown regardless of the tree's age, dominance or crown size. This is the method still used today. The relative degree of risk to bark beetle attack is judged by the degree of crown decadence and is divided into four classes of risk:

Risk I. Low risk trees. Trees whose crowns are healthy, with no weakened portions.

Risk II. Moderate risk trees. Trees with predominately thrifty foliage, but which have a small amount of dead and dying twigs in the upper branches of the crown.

Risk III. High risk trees. Trees with a considerable amount of branch dieback, and the needles are shorter and fewer in number.

Risk IV. Very high risk trees. Trees in advanced stages of decadence with short, sparse foliage; these trees often have active top-killing and/or partial insect infestations or disease (fig. 4).

Salman believed that trees showing symptoms of high risk would be those most frequently attacked and killed by bark beetles. By studying almost 20,000 trees on 12 sample plots in the Lassen and Modoc National Forests over a two-year period, he subsequently showed that the beetles attacked and killed approximately 30 high risk trees to every one in the low risk category.

The first test of sanitation treatment took place in Blacks Mountain Experimental Forest in 1937. In this operation, only about 11 percent of the trees were removed, representing 15 percent of the volume in board feet. Studies to observe the effects of this treatment have been painstakingly conducted and documented for over 20 years, and show the sanitation treatment to be highly effective in the pine stands of northeastern California. The following graphs (fig. 5) taken from the published results of this experiment (Wickman and Eaton, 1962) clearly indicate the beneficial effects of the treatment which have persisted to the present time.

Figure 4. The large tree above would fall into Salman's very high risk category.

Photo by J. R. Pierce

This early research work showed that pine trees display various degrees of resistance to invasion by their bark beetle enemies.

Another early observation was that, under epidemic conditions, a large bark beetle population often kills large groups of trees, seemingly without regard to tree condition (Miller and Keen, 1960). This apparent contradiction is explained by the fact that bark beetles concentrate around centers of infestation. After the first tree is successfully invaded, more beetles are attracted to the spot.[1/] As more and more beetles arrive, they are able to overcome and kill trees of greater resistance by attacking in large numbers. In this way, high risk trees constitute a real danger to neighboring trees.

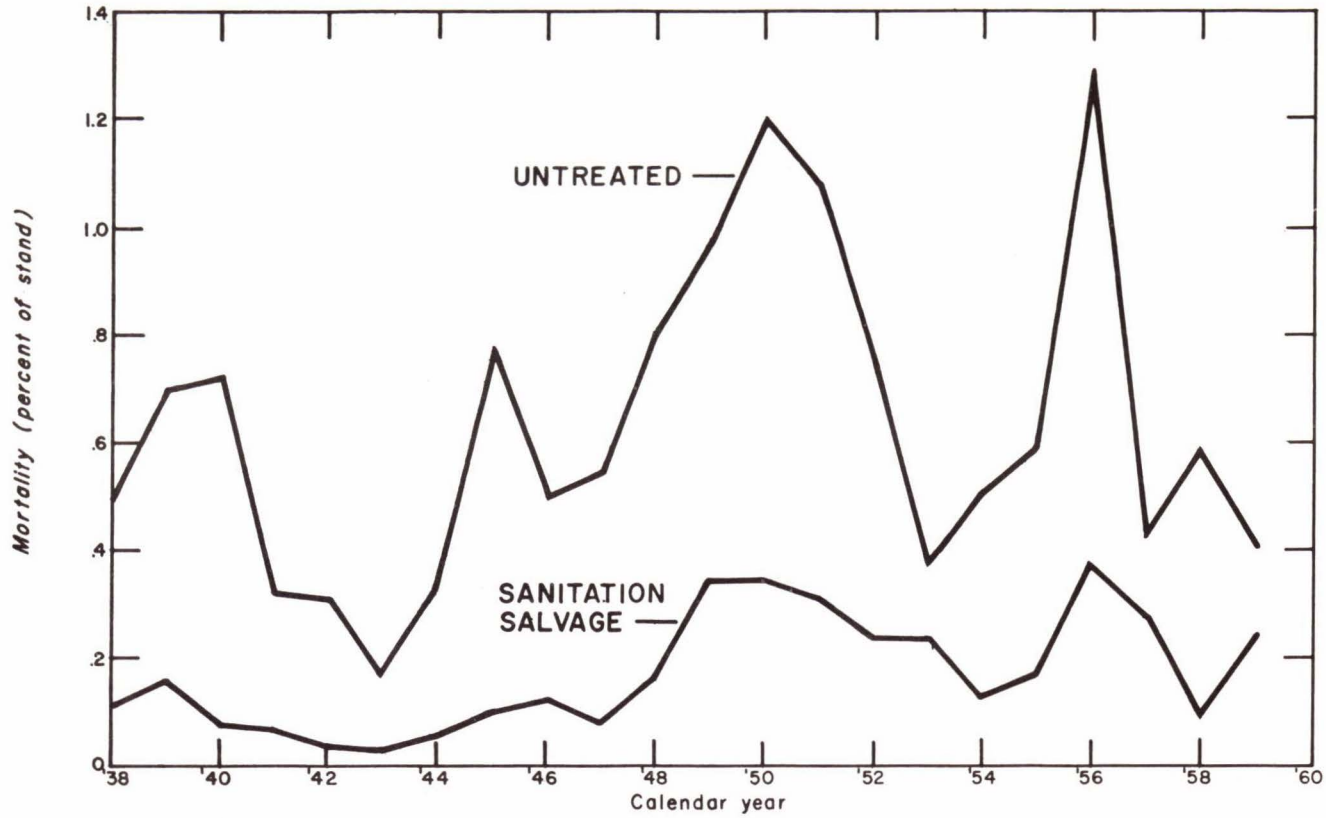
Other differences between high risk and low risk trees have been studied which are important in the sanitation treatment concept. Hall (Hall, 1942) demonstrated, by caging standing infested ponderosa pines and collecting emerging adult beetles, that when Risk I trees became infested, they produced an average of 18 beetles per square foot compared to 24 per square foot in Risk II, 44 in Risk III, and 115 in Risk IV trees.

Trees classified into various risk categories differ according to phloem[2/] thickness, pitch producing ability and suitability for bark beetle brood production. Hall (Hall, 1949) discovered a significant difference in the phloem thickness between high and low risk ponderosa pine trees. The phloem layer in Risk I trees is more than two times as thick as that in Risk IV trees. Callaham (Callaham, 1952) found that low risk trees continue to produce pitch from attack points for a much longer period of time than high risk trees. Exudation of pitch is the way in which pine trees combat attacks by bark beetles. The pitch is somewhat toxic to the beetles and is also a mechanical barrier to the penetrating insect. A large flow of pitch can often literally "pitch out" the invading beetles.

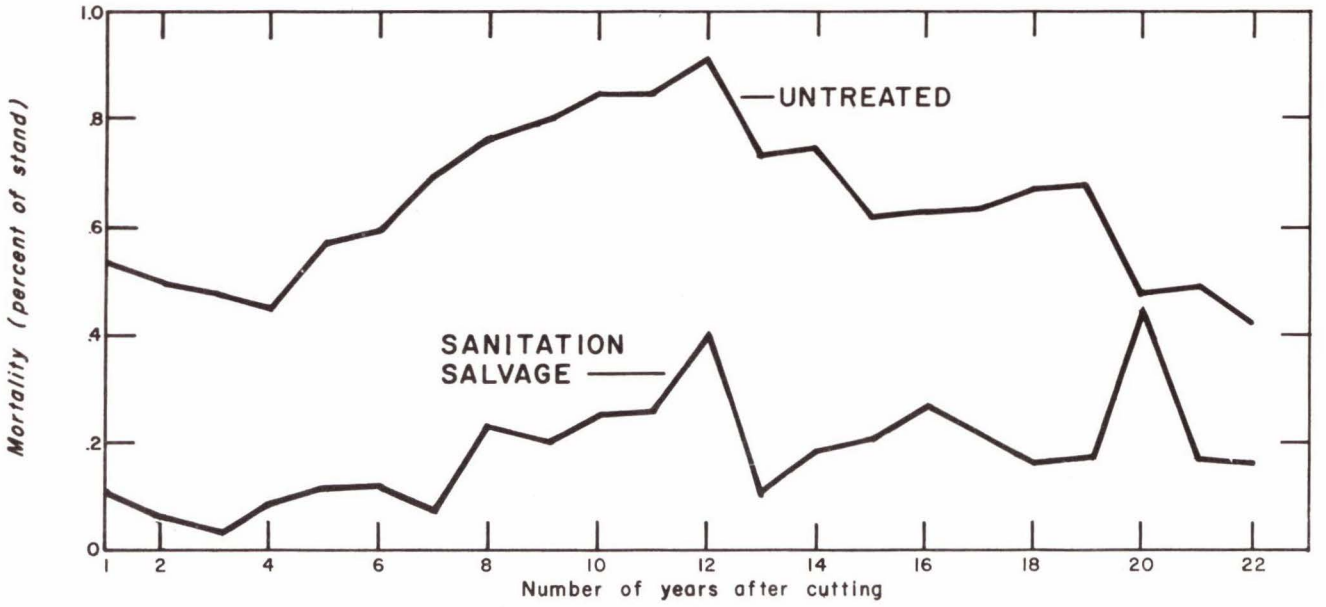
Undoubtedly, high and low risk trees are distinguishably different, and these differences correlate with the susceptibility of trees to bark beetle attack.

1/ Although not fully understood, this phenomenon is believed to be due to attractants emitted by the beetles which have successfully invaded a tree.

2/ Phloem is that portion of the inner bark which functions in the conduction of food materials.



Insect-caused pine sawtimber mortality on cut and uncut compartments for the calendar years 1938 to 1959.



Insect-caused pine sawtimber mortality on cut and uncut compartments in successive numbers of years after cutting.

Figure 5. A twenty-two year record comparing treated and untreated compartments at Blacks Mountain Experimental Forest. (U.S. Forest Service, Pacific Southwest Forest & Range Experiment Station, Berkeley, California).

THE RESULTS OF SANITATION TREATMENT

Although sanitation treatment had been used effectively in northern California for 15 years, it was not tested in the forests of southern California until 1953. During 1950 and 1951, bark beetle tree killing was severe in the Barton Flats Recreation Area of the San Bernardino National Forest. The application of direct control measures to combat this problem had not been successful. In 1950, direct control crews burned 554 bark beetle-infested trees on 2,600 acres. This was an incomplete job since money was not available to treat the entire area. The following year, 1,100 infested trees on 6,000 acres were spotted; loss from the infestation was estimated to exceed 200 board feet per acre (Hall, 1958).

The original recommendation to use sanitation treatment at Barton Flats came from Forest Service Entomologist J. W. Bongberg, who had worked on the sanitation treatment program in northern California. His report (Bongberg, 1952) analysing the problem and recommending this action contains the following description of the situation:

> "The variable results in past efforts to control bark beetles by direct artificial methods in the Barton Flats Recreational Area, and the complete failure of the program that was undertaken during 1950-1951, points to the need of revised measures to cope with this problem. Although the rate of tree killing might be kept to a low endemic level by large expenditures for direct measures of control, such procedures would not solve the underlying causes of the heavy tree mortality each year. A more logical, practical, and economical approach for control on a lasting basis is to bug-proof the area by a selective removal of the high risk trees. An operation of this sort, properly planned and executed, would involve the removal of only a small percentage of the green stand volume; it would reduce subsequent tree mortality to a minimum level for a period of years; prevent bark beetles from breeding large populations with resultant possibilities of epidemic losses; and in other ways materially benefit the Barton Flats Area for recreational use."

The project to apply sanitation treatment to the Barton Flats problem was carried out between October 1953 and December 1954.

The late W. S. Rosecrans, when Chairman of the California State Board of Forestry, pointed out (Rosecrans, 1957) that the sanitation treatment program in southern California was a history making forestry project which developed a new concept of forest management in recreation areas. He also reported ready acceptance, by the general public, of the principle of removing decadent trees by logging in areas where no timber cutting had been done for almost half a century.

Hall (Hall, 1958) reported on the encouraging results of sanitation treatment at Barton Flats during the first two-year period after

treatment. He estimated that losses dropped to less than 10 percent of those prevailing prior to treatment.

Following two years of successful experience with sanitation treatment at Barton Flats, this program was expanded to include other similar insect problem areas. Since that time, sanitation treatment has been undertaken on some 55,467 acres on the San Bernardino National Forest, 14,445 acres on the Los Padres National Forest, and 11,348 acres on the Angeles National Forest (fig. 6).

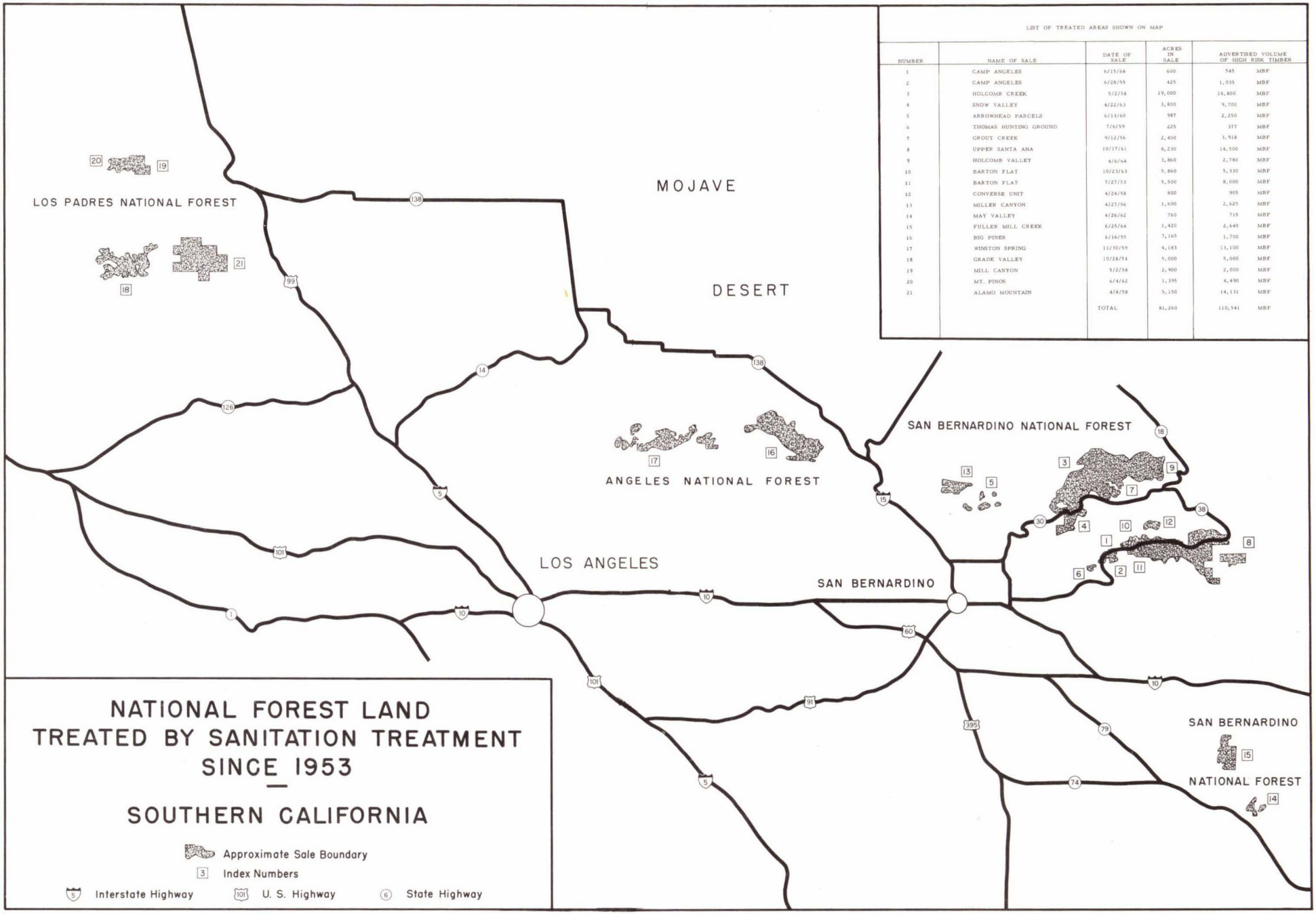
Now, after over a decade of experience, the results have again been reviewed. Sanitation treatment in southern California has been an action program, not a research project, so the data available are not as detailed as those accumulated in the Blacks Mountain studies which were conducted for research. However, several case histories of sanitation treatment in southern California firmly support this method as a positive management practice. A summary of the case histories follows:

Case History I - Barton Flats 1953, San Bernardino National Forest

This was the initial trial of sanitation treatment in southern California. Here, there is a double check on treatment results. First, there was a good estimate of the epidemic loss before sanitation treatment was applied which can be compared with the loss recorded after treatment. Second, two five-acre plots were purposely left untreated in the area, and a comparison between treated and untreated areas is possible on a small sample basis. The insects killing the trees were mainly the western pine beetle, (Dendroctonus brevicomis LeC.), the Jeffrey pine beetle, (D. ponderosae Hopk.), and the California flatheaded borer, (Melanophila californica VanD.).

Following the initial sanitation treatment in Barton Flats in 1953-1954, direct control of bark beetles was continued in order to afford the area the greatest possible protection. Losses remained low until the summer of 1961. Beginning in the summer of 1961, tree mortality again soared to the high pre-treatment level. The appearance of the stand in 1961 indicated that extreme, prolonged drought had accelerated the development of high risk trees until large numbers of Risk III and Risk IV trees were again present. A re-assessment of the untreated plots in 1962 confirmed this, and showed that the number of Risk III trees had increased by 113 percent, and the number of Risk IV trees had increased by 133 percent since 1952 when the plots had been established (Bates, 1963). Because of the high death rate of trees and the increase in the number of high risk trees, the Barton Flats Area was treated again in 1964.

This first trial of sanitation treatment shows an impressive record of accomplishment. Immediately following the original treatment, tree losses to insects were reduced 93 percent compared to the pre-treatment loss level. For the entire period between the completion of the original treatment and the need for a re-treatment became apparent, the



LIST OF TREATED AREAS SHOWN ON MAP

NUMBER	NAME OF SALE	DATE OF SALE	ACRES IN SALE	ADVERTISED VOLUME OF HIGH RISK TIMBER
1	CAMP ANGELES	6/15/64	600	545 MBF
2	CAMP ANGELES	6/28/55	425	1,035 MBF
3	HOLCOMB CREEK	5/2/58	19,000	14,800 MBF
4	SNOW VALLEY	4/22/63	3,800	9,700 MBF
5	ARROWHEAD PARCELS	6/13/60	987	2,250 MBF
6	THOMAS HUNTING GROUND	7/6/59	225	377 MBF
7	GROUT CREEK	9/12/56	2,400	3,918 MBF
8	UPPER SANTA ANA	10/17/61	8,230	14,500 MBF
9	HOLCOMB VALLEY	4/6/64	3,860	2,780 MBF
10	BARTON FLAT	10/23/63	5,860	5,330 MBF
11	BARTON FLAT	7/27/53	5,500	8,000 MBF
12	CONVERSE UNIT	4/24/58	800	905 MBF
13	MILLER CANYON	4/27/56	1,600	2,625 MBF
14	MAY VALLEY	4/26/62	760	715 MBF
15	FULLER MILL CREEK	6/25/64	1,420	2,640 MBF
16	BIG PINES	6/16/55	7,165	1,700 MBF
17	WINSTON SPRING	11/30/59	4,183	13,100 MBF
18	GRADE VALLEY	10/28/54	5,000	5,000 MBF
19	MILL CANYON	5/2/58	2,900	2,000 MBF
20	MT. PINOS	6/4/62	1,395	4,490 MBF
21	ALAMO MOUNTAIN	4/8/58	5,150	14,131 MBF
		TOTAL	81,260	110,541 MBF

accumulated losses on the treated area were nearly 60 percent less than on the untreated plots.

Case History II - Big Pines 1955, Angeles National Forest

This is one of the oldest examples of sanitation treatment in southern California. At Big Pines, as at Barton Flats, sanitation treatment has been supplemented by direct control. On this area the losses since treatment have remained low. During the most severe part (1960 and 1961) of the current drought cycle, losses turned upward for a period, but never reached epidemic levels. Since then, loss figures have returned to a very low level, and there is no apparent need to re-treat the area for some time to come. In this case, the insect which was successfully controlled was the California flatheaded borer.

Timber cruise figures obtained in preparation for treating Big Pines showed an epidemic loss of 769 board feet per acre. Immediately following the removal of high risk trees, losses were an insignificant three board feet per acre. The highest loss since then was 69 board feet per acre recorded in 1961, and this dropped back to 15 board feet per acre in 1962.

Case History III - May Valley-Baldy Mountain Epidemic of 1959-1964

A serious epidemic of the western pine beetle, as well as the California flatheaded borer, began in 1958 at May Valley (Anonymous, 1959) and in 1959 at Baldy Mountain. These outbreaks soon merged and eventually spread south to the base of Thomas Mountain. The May Valley portion of the outbreak was controlled by sanitation treatment in 1962. The rest of the epidemic area supported Coulter pine and Jeffrey pine of poor quality, and due to steep terrain, treatment was not economically possible.

Of the 2,460 acres treated by sanitation, 1,700 acres were privately-owned and 760 acres were National Forest lands (Horn, 1963). The private and public ownerships were simultaneously treated. This was an outstanding example of cooperation between private owners and the Forest Service in controlling a persistent bark beetle epidemic. The technical aspects of the program on private land were handled by a consulting forester employed by the landowners.

Epidemic losses had been occurring in the May Valley-Baldy Mountain stands for at least three years when the May Valley portion of the outbreak was treated in the summer of 1962. Best estimates of the loss which had accumulated up to the treatment period showed 477 board feet per acre. This amounted to 10.8 percent of the estimated original stand volume of 4,438 board feet per acre (Pierce, 1964).

In 1964, two years after the completion of the treatment, a special aerial photographic study of the May Valley-Baldy Mountain epidemic was initiated in cooperation with the University of California. The study was designed to document the results of sanitation treatment by means of aerial and ground cruise plots of treated and untreated areas. Due to

delays in obtaining suitable photography and completing field work, and the volume of photo interpretation and analysis, the study will not be completed until late 1965. However, two general conclusions are appearing (correspondence from Gene Thorley, University of California):

(a) Tree Mortality - the magnitude of recent tree mortality is much less in treated areas than in surrounding untreated areas.

(b) Size of Infested Groups - the size of groups of recently infested trees in treated areas is much smaller than in untreated areas. Treated areas contain groups of 1 to 7 trees whereas untreated areas contain groups of 1 to 40 trees.

Case History IV - Alamo Mountain 1960, Los Padres National Forest

Alamo Mountain supports about 7,000 acres of some of the finest forest in southern California. A serious bark beetle epidemic developed following a forest fire which burned a portion of the area in 1951. In 1956, a detailed appraisal survey measured a high level of tree killing by bark beetles. Sanitation treatment of the area was recommended at that time (Hall, 1956).. This treatment was delayed until 1958 because of objections raised to opening this inaccessible area to do the work. After consideration of the objections, the insect control program was finally initiated in 1958 and completed in 1960.

The survey of 1956 by Hall established that in five years some 13,000 trees had been killed by bark beetles. The average annual loss was over three million board feet per year, equivalent to some 2,500 trees destroyed annually.

After the sanitation treatment was completed, a direct control plan was initiated to guard against future outbreaks. The direct control plan was to treat all infested trees in accessible areas with insecticide, and in less accessible locations, to treat only group losses. Under this plan, 91 infested trees have been treated during the period 1961-1964. This control record, plus subsequent aerial and ground inspections, shows that insect-caused tree mortality dropped to an insignificant level after sanitation treatment was applied.

RESULTS WHERE SANITATION TREATMENT WAS NOT USED

In analysing sanitation treatment to prevent bark beetle epidemics, alternatives also should be considered. If a bark beetle epidemic exists or threatens an area, and sanitation treatment is not applied, the Forest Service may apply direct control or elect to apply no control at all. Due to certain limitations of sanitation treatment, there are several timbered areas in southern California which are managed in this manner, i.e., direct control or no control at all.

Case History V - Ranger Peak-Figueroa Mountain Direct Control Units, Los Padres National Forest

In the particular situation at Ranger Peak and Figueroa Mountain, sanitation treatment was not practical because of the long distance to available markets. Therefore, in 1962, an excellent opportunity arose to evaluate these alternatives. A western pine beetle outbreak developed on two adjacent ridges. The stand on one ridge (Figueroa Mountain), had received continuous direct control, but the other ridge (Ranger Peak), had received no control. Both areas are small in size and support excellent stands of ponderosa pine. The small size of the areas permitted a good program of direct control and made feasible a detailed study (Swain, 1963) of the results. In 1961, when the buildup began, the uncontrolled area, Ranger Peak, lost 118 trees which amounted to 6.2 percent of the stand volume. At Figueroa Mountain, where direct control had been applied continuously, the loss was 171 trees or 5.5 percent. In 1962, the insect population at Ranger Peak erupted, killing 991 trees or 28.6 percent of the stand volume. At Figueroa Mountain, where the direct control program had been continued, the 1962 loss was 229 trees, or 4.7 percent of the stand volume. Because of these conclusive findings, direct control was also begun at Ranger Peak about midway through the 1962 season.

This record indicates that lack of control resulted in catastrophic losses at Ranger Peak. Direct control, on the other hand, suppressed the loss to about 5 percent of the stand in a comparable area. The 5 percent loss at Figueroa Mountain, however, is 10 times greater than the 0.5 percent level considered acceptable. Direct control alone will not assure that the loss can be reduced to tolerable limits needed to perpetuate the forest.

DISCUSSION

This experience and others have strengthened our conclusions about bark beetle control in southern California. If all control action is withheld from a developing bark beetle epidemic, very heavy tree losses will usually occur in a brief period of time. If the outbreaks are allowed to persist or re-occur frequently, timber stands over large areas can be destroyed.

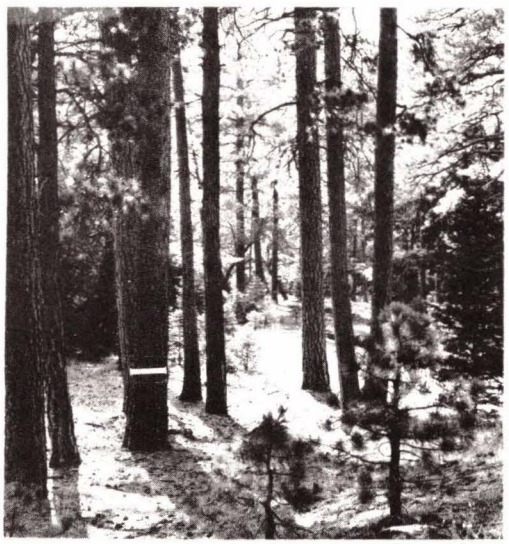
Experience indicates also that direct control is a stop-gap measure. Direct control is very expensive and does not alter any of the basic factors causing bark beetle outbreaks. It does not cure epidemics once established, but merely serves as a delaying action to reduce the level of loss and must be continuously applied to be effective.

On the other hand, sanitation treatment during the past decade in southern California shows a high degree of success. Records as reviewed previously, indicate that insect-caused tree killing has sharply declined in treated areas. It must be understood also that the favorable results of sanitation treatment have been achieved in southern California during a period of extreme hazard from bark beetle damage. As is evidenced by catastrophic epidemics in some untreated areas and heavy losses in areas treated by direct control, we are going through a prolonged period of high hazard caused mainly by drought.

Although the reduction of overall tree losses due to bark beetle attack has been the primary accomplishment of the sanitation treatment program, this is by no means the only basis for continuing this program in the forests of southern California. Of great importance also is the pattern of loss. Large indiscriminate killing of trees in groups with the resultant loss of shade and aesthetic value, causes greater damage to campgrounds and recreation areas than a removal of a small number of carefully selected trees by sanitation treatment.

The following photographs (fig. 7) show that sanitation treatment usually removes only scattered single trees as opposed to group killing common in bark beetle outbreaks.

Treated site 9 years after treatment. Only 1 tree of the group was removed.



Above two areas have been marked for treatment. Again, only 1 tree among several was selected for removal.

Figure 7. Trees removed by sanitation treatment.
Photos by J. L Averell

LIMITATIONS OF SANITATION TREATMENT

Sanitation treatment is, of course, not the entire answer to the bark beetle problem. Several limitations in this method of suppression prevent its universal application to all forested areas threatened by bark beetles. For example: The identification of high risk trees has so far been possible only with ponderosa and Jeffrey pine growing in the drier portions of their range. Another key element in the sanitation treatment program is the removal of high risk trees through commercial timber sale arrangements. It is necessary that the value of the high risk trees to be harvested exceeds the cost of removal. Factors here are: Distance to available markets, and topography of the treated areas, which must be gentle enough to permit the operation of logging equipment. Many areas are untreatable because of low value of the timber, excessive distance to sawmill or inoperable terrain.

The size of the tree is also important. Not only are trees from sapling or pole stands ordinarily unmerchantable but these young trees usually do not display visible symptoms of high risk.

Landownership also restricts the application of sanitation treatment. The management of private land is, of course, the responsibility of the owners; some private owners elect to apply sanitation treatment, and others do not. Small parcels usually cannot be treated economically.

Timber stands located in areas where access development or timber cutting are prohibited are ineligible for sanitation treatment except under extreme emergencies.

Timber in a Wilderness Area may not be treated in any way without the prior approval of the Chief of the Forest Service.

Because of limitations of sanitation treatment as those listed above, it is necessary to rely on expensive direct control operations to combat many bark beetle outbreaks. For example, in the important recreation areas around Lake Arrowhead, direct control has been used the most due to the large number of small ownerships intermingled with and adjacent to National Forest land.

The protection of young forests is also a serious problem. Young trees often grow in such dense stands that the growth capacity of the site is largely wasted by competition between trees for growing space. At times the stress of overcrowding weakens the trees to a point that a bark beetle outbreak is triggered by some common adversity such as a dry summer, or winter storm damage. The results of bark beetle damage under these conditions have been as devastating as wild fire in some cases.

In the future, there is a need to find new ways of applying the sanitation treatment concept or to develop other cultural practices to protect the forests from pests. Forest protection through forest management is a key to assuring long-term watershed protection and recreational opportunities. Providing this protection over large areas is often a very difficult mission. The approach which is most practical, economical and least destructive of natural beauty of the forest is the sanitation treatment.

REFERENCES

Anonymous.
1959. Forest pest conditions in California, 1959. Official Report of the California Forest Pest Control Action Council. California Division of Forestry, Sacramento, California. 35 pp., illus.

Bates, James C.
1963. Commercial sales - Barton Flats Sale 1953 and Proposed 1963. High risk plots. Memorandum 2430 dated August 12, 1963. U. S. Forest Service, San Bernardino National Forest, San Bernardino, California. 7 pp., typed.

Bongberg, J. W.
1952. Bark beetle control on the Barton Flats Recreational Areas through the selective removal of high risk trees. U. S. Bureau of Entomology and Plant Quarantine, Forest Insect Laboratory, Berkeley, California. 3 pp., typed.

Callaham, R. Z.
1952. The role of quantitative oleoresin production in the susceptibility of pines to bark beetles. U. S. Bureau of Entomology and Plant Quarantine, Forest Insect Laboratory, Berkeley, California.

Hall, Ralph C.
1942. High risk trees are high producers of western pine beetles. U. S. Bureau of Entomology and Plant Quarantine, Forest Insect Laboratory, Berkeley, California. 1 p., illus.

_____.
1949. An ecological study of Ips confusus in northern California. Progress Report - Season of 1947 and 1948. U. S. Bureau of Entomology and Plant Quarantine, Forest Insect Laboratory, Berkeley, California. 22 pp., illus.

_____.
1956. Forest insect conditions, Alamo Mountain - Los Padres National Forest. Appraisal survey spring, 1956. U. S. Forest Service, California Forest and Range Experiment Station, Berkeley, California. 7 pp., processed.

_____.
1958. Sanitation-salvage controls bark beetles in southern California recreation areas. Journal Forestry, 56 (1): 9-11, illus.

Hopkins, A. D.
1909. Bark beetles of the genus Dendroctonus. U. S. Department of Agriculture, Bulletin 83, Part I. 169 pp., illus.

Horn, J. M.
1963. Forest insect and disease control (May Valley Sale). Notes on May Valley Sanitation-Salvage Sale, San Bernardino National Forest, San Jacinto Ranger District. Memorandum 5200 dated February 20, 1963, U. S. Forest Service, San Bernardino National Forest, San Bernardino, California. 3 pp., typed.

Miller, J. M. and Keen, F. P.
1960. Biology and control of the western pine beetle. A summary of the first fifty years of research. Miscellaneous Publication 800, U. S. Department of Agriculture, Forest Service, Washington, D. C. 381 pp., illus.

Person, H. L.
1928. Tree selection by the western pine beetle. Journal Forestry, 26 (5): 564-578, illus.

Pierce, John R.
1962. Insect and disease control (San Bernardino). Summary report on insect control activities Fiscal Year 1962. Memorandum 5200, dated October 17, 1962. U. S. Forest Service, Division of Timber Management, San Francisco, California. 38 pp., typed.

_____.
1964. Forest insect and disease control (San Bernardino) - Insects). Memorandum 5200, dated June 23, 1964. U. S. Forest Service, Division of Timber Management, San Francisco, California. 1 p., typed.

Rosecrans, W. S.
1957. Logging in recreational forests. American Forests 63 (5): 20-22, 56-59, illus.

Salman K. A.
1937. Preliminary results - Tests marking of tree susceptibility. Memorandum dated December 14, 1937. U. S. Bureau of Entomology and Plant Quarantine, Forest Insect Laboratory, Berkeley, California.

Swain, K. M.
1963. Analysis of the Figueroa Mountain - Ranger Peak insect outbreak. Memorandum 5200, dated July 12, 1963. U. S. Forest Service, Division of Timber Management, San Francisco, California. 9 pp., processed.

Wickman, Boyd E. and Eaton, Charles B.
1962.
The effects of sanitation-salvage cutting on insect-caused mortality at Blacks Mountain Experimental Forest, 1938-1959. Technical Paper No. 66, U. S. Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. 39 pp., illus.

GPO 971-071